

Description

High-Pressure Discharge Lamp Lighting Device and Lighting Fixture

Technical Field

5 [0001] This invention relates to a high-pressure discharge lamp lighting device and a lighting fixture using it.

Background Art

[0002] JP-A-2003-223997 proposes a high-pressure discharge lamp lighting device having a capability of deep dimming. FIG. 22 shows change rate of lamp power to voltage across lamp V_{1a}. Circuit operates at the intersection point of the output characteristic of a lighting device indicated by a dotted line a, b in the figure and the lamp characteristic indicated by a heavy solid line c. If the circuit is thus operated, a constant-voltage characteristic can be taken in a comparatively high output dimming range (for example, 40% to 100%) until the voltage across lamp V_{1a} turns to rise as shown in a in FIG. 22, and roughly constant power can be obtained for fluctuation of lamp impedance caused by the individual difference and the life of lamp; the circuit operates with a constant-current characteristic in a comparatively low output dimming range (for example, 40% or less) where the voltage across lamp V_{1a} turns to rise as shown in b in FIG. 22, so that an operation point of an intersection point with the lamp

characteristic can be taken, gong out does not occur, stable lighting can be performed, and the dimming range can be enlarged.

[0003] FIG. 23 shows target values of lamp current I_{la} in output characteristics a and b in FIG. 22. As described above, the target value of the lamp current I_{la} is decreased in response to an increase in the voltage across lamp V_{la} in the dimming area of the output characteristic a, thereby performing rough constant-power control, and the target value of the lamp current I_{la} is made constant in response to an increase in the voltage across lamp V_{la} in the dimming area of the output characteristic b, thereby performing constant-current control.

[0004] A discharge lamp lighting device of a characteristic as shown in JP-A-6-111987 is also known for the purpose of widening the dimming range. FIG. 24 shows the characteristic and shows lamp voltage V_{la} relative to lamp current I_{la} of the discharge lamp lighting device. Assuming that the current command value at the instant at which the lamp voltage V_{la} exceeds a threshold value V_{th} is X, if adjustment is made so as to output a current command value Y or Z lower than X, it crosses voltage-current curve Q of discharge lamp at a y point or a z point and the light state can be still maintained. Thus, when the lamp voltage V_{la} is lower than the threshold value V_{th} , constant-power dimming is performed, and

constant-current dimming is performed in the range in which the lamp voltage V_{la} is equal to or greater than the threshold value V_{th} . This means that the dimming range is widened to a smaller luminance area.

5 Patent document 1: JP-A-2003-223997

Patent document 2: JP-A-6-111987

Disclosure of the Invention

Problems to be Solved by the Invention

[0005] In the arts in patent documents 1 and 2, the lighting device is provided with a constant-current characteristic to dim the high-pressure discharge lamp to a low luminous flux level for reliably maintaining the operation point of the output characteristic of the lighting device and the lamp characteristic as compared with dimming control based on constant power. However, for example, in a deeper dimming area with illuminance ratio 20% or less assuming that the rated lighting time is 100%, the lamp voltage rises rapidly as the dimming becomes deeper as indicated by the heavy solid line c in FIG. 22 and thus it becomes difficult to maintain the operation point of the lighting device and the lamp characteristic, resulting in occurrence of going out; this is a defect.

[0006] It is therefore an object of the invention to provide a high-pressure discharge lamp lighting device capable of executing dimming up to a lower luminous flux level than

the dimming lower limit obtained by performing constant-current control as described in the related art example.

Means For Solving the Problems

5 [0007] To solve the problem described above, according to the invention, there is provided a high-pressure discharge lamp lighting device including a power conversion unit 1 for supplying AC power to a high-pressure discharge lamp DL as a load with a DC power supply E as an input power supply for
10 performing all lighting or dimming lighting as shown in FIG. 2, wherein in an area where the voltage across the high-pressure discharge lamp DL grows as dimming deepens, the output characteristic of the power conversion unit 1 is a characteristic for increasing the output current of the power
15 conversion unit 1 in response to an increase in the output voltage of the power conversion unit 1 as shown in characteristic BC1 in FIG. 1 (b).

Advantages of the Invention

[0008] According to the invention as claimed in claim 1,
20 low luminous lighting can be stably executed in a wider range as compared with the constant-current control in the related art.

According to the invention as claimed in claim 2, change amount of lamp current/change amount of lamp voltage is made
25 constant, whereby control can be facilitated.

According to the invention as claimed in claim 3, if dimming is deepened, the operation point is provided reliably, so that low luminous lighting can be stably executed in a wider range.

5 According to the invention as claimed in claim 4, after start, the output characteristic of the lighting device is provided from lamp voltage 0 V to the voltage at the operation point, so that low luminous dimming starting can be executed reliably, for example.

10 According to the invention as claimed in claim 5, the value of the lamp voltage at the switch point between constant-current control and the operation according to the invention is changed in response to dimming, so that brightness adjustment in a low luminous area can be made easily.

15 [0009] According to the invention as claimed in claim 6, the lamp power in the vicinity of the dimming lower limit can be set to power at the same degree as that at the initial time for variation of the lamp with time.

According to the invention as claimed in claim 7, smooth
20 and continuous control can be executed in a wide range of the rated lighting to the dimming lower limit using the constant-power control, the intermediate control of the constant-power control and the constant-current control, the constant-current control, and the low luminous lighting time
25 control of the invention in combination.

According to the invention as claimed in claim 8, 9, 10, control can be facilitated and can be realized by a simple control circuit.

According to the invention as claimed in claim 11, the 5 data table of the microcontroller is referenced, whereby the control operation switching circuit responsive to the lamp voltage, etc., becomes unnecessary and the circuit can be simplified.

According to the invention as claimed in claim 12, the 10 amount of data to be stored in the data table of the microcontroller can be lessened.

According to the invention as claimed in claim 13, a lighting fixture that can be dimmed up to a lower level than that in the related arts can be provided.

15 Brief Description of the Drawings

[0010] FIG. 1 is a characteristic drawing to show the operation of a first embodiment of the invention.

FIG. 2 is a circuit diagram to show a circuit configuration example of the first embodiment of the invention.

20 FIG. 3 is a circuit diagram to show a specific circuit configuration example of the first embodiment of the invention.

FIG. 4 is a characteristic drawing to show measurement data provided when dimming control of a high-pressure discharge lamp is performed using low luminous lighting control of the invention.

25 invention.

FIG. 5 is a characteristic drawing to show measurement data provided when dimming control of a high-pressure discharge lamp is performed using constant-current control in a related art.

FIG. 6 is a characteristic drawing to show the operation of
5 a second embodiment of the invention.

FIG. 7 is a characteristic drawing to show the operation of
a third embodiment of the invention.

FIG. 8 is a circuit diagram to show a circuit configuration example of the third embodiment of the invention.

10 FIG. 9 is a characteristic drawing to show the operation of
a fourth embodiment of the invention.

FIG. 10 is a circuit diagram to show a circuit configuration example of the fourth embodiment of the invention.

15 FIG. 11 is a circuit diagram to show another circuit configuration example of the fourth embodiment of the
invention.

FIG. 12 is a characteristic drawing to show the operation of
a fifth embodiment of the invention.

20 FIG. 13 is a circuit diagram to show a circuit configuration example of the fifth embodiment of the invention.

FIG. 14 is a characteristic drawing to show the operation of
a sixth embodiment of the invention.

FIG. 15 is a characteristic drawing to show the operation of
the sixth embodiment of the invention.

25 FIG. 16 is a characteristic drawing to show the operation of

the sixth embodiment of the invention.

FIG. 17 is a circuit diagram to show a circuit configuration example of the sixth embodiment of the invention.

FIG. 18 is a circuit diagram to show another example of a
5 specific circuit of a lighting device of the invention.

FIG. 19 is a circuit diagram to show still another example of the specific circuit of the lighting device of the invention.

FIG. 20 is a circuit diagram to show a different example of the specific circuit of the lighting device of the invention.

10 FIG. 21 is a perspective view to show an example of the appearance of a lighting fixture using the lighting device of the invention.

FIG. 22 is a characteristic drawing of a first related art example.

15 FIG. 23 is an operation schematic representation of the first related art example.

FIG. 24 is a characteristic drawing of a second related art example.

Description of Reference Numerals

20 [0011] E DC power supply

1 Power conversion unit

2 Dimmer

3 DC/DC conversion unit

4 DC/AC conversion unit

25 5 Control circuit

DL High-pressure discharge lamp

Best Mode for Carrying out the Invention

[0012] (First embodiment)

FIGS. 1 (a) and (b) show the operation characteristics of a discharge lamp lighting device according to a first embodiment of the invention; FIG. 1 (a) shows the output characteristic of a lighting device and lamp characteristic on a graph of lamp power W relative to lamp voltage V . In the figures, a solid line LC shown so as to pass through points a and b indicates the lamp characteristic and a line BC1 made up of a solid line and a dotted line shown so as to pass through points A and B indicates the output characteristic of the lighting device according to the embodiment. For comparison, the output characteristic based on constant-current control shown in the related art example is indicated by a dotted line BC2.

[0013] In the lamp characteristic LC, if dimming is deepened from the rated lighting indicated by the point a, namely, the lamp power W is lessened, the lamp voltage V becomes roughly constant or a little lowers. If dimming is still executed although the lamp voltage reaches one point (V_b), the lamp voltage rapidly rises after the point b.

[0014] At this time, an intersection point CP of the output characteristic BC1 of the lighting device and the lamp characteristic LC, indicated by a white circle becomes the

operation point of the lamp. The output characteristic of the lighting device is made a characteristic like BC1, whereby the characteristic curves of the lamp characteristic LC and the output characteristic BC1 cross orthogonally and thus the 5 operation point is reliably provided and when dimming is further deepened, it also becomes easy to maintain the operation point. Consequently, it is made possible to stably light up to deep dimming.

[0015] In this connection, in constant-current control 10 as indicated in the related art example, namely, the output characteristic indicated by the dotted line BC2, the lamp also operates at the intersection point CP of the lamp characteristic LC and the output characteristic BC2; since the 15 lamp characteristic LC and the output characteristic BC2 are close to each other in gradient as compared with the operation described above and thus if dimming is further deepened, going out easily occurs.

[0016] FIG. 1 (b) is provided by replacing the characteristics in FIG. 1 (a) with a graph of lamp voltage 20 V and lamp current I and shows those corresponding to the lamp characteristic LC and the output characteristics BC1 and BC2 in FIG. 1 (a). It is also seen in FIG. 1 (b) that the output characteristic BC1 and the lamp characteristic LC cross orthogonally and the operation point is reliably provided. 25 Thus, it is made possible to stably light up to deep dimming.

[0017] If the gradient in the vicinity of the operation point in FIG. 1 (b), namely, (change amount of lamp current I/change amount of lamp voltage V) is roughly constant, circuit design is facilitated.

5 [0018] For the output characteristic BC2 indicating constant-current control, if dimming is further deepened, the characteristic gradient becomes similar to that of the lamp characteristic LC and thus the operation point becomes unstable and going out easily occurs.

10 [0019] FIG. 2 shows the circuit configuration of the lighting device according to the embodiment. The lighting device is made up of a DC power supply E, a power conversion unit 1, a high-pressure discharge lamp DL connected to the power conversion unit 1, and a dimmer 2 for transmitting a dimming signal to the power conversion unit 1.

15 [0020] The power conversion unit 1 includes a DC/DC conversion unit 3 connected to both ends of the DC power supply E, a DC/AC conversion unit 4 connected to output of the DC/DC conversion unit 3, and a control circuit 5 for performing on/off control of a switching element Q of the DC/DC conversion unit 3.

20 [0021] The control circuit 5 is made up of a lamp current detection circuit 51 for detecting a current flowing into the high-pressure discharge lamp DL and outputting a current lamp current value I_{la} , a lamp current command value computation

circuit 52 for receiving a signal from the dimmer 2 and computing a lamp current command value I_{la}^* , and a gain circuit 53 for multiplying the difference between the lamp current command value I_{la}^* and the detection value I_{la} by α , and 5 operates so that the lamp current command value I_{la}^* and the detection value I_{la} roughly match by turning on/off the switching element Q of the DC/DC conversion unit 3 based on the pulse width responsive to the output of the gain circuit 53.

10 [0022] FIG. 3 is a circuit diagram to show the configuration in FIG. 2 in more detail. The DC power supply E is made up of an AC power supply Vs, a diode bridge DB made up of diodes D1, D2, D3, and D4, a step-up chopper circuit made up of an inductance L1, a switching element Q1, a diode D5, 15 and an electrolytic capacitor C1, and a control circuit 6 of the step-up chopper circuit. The control circuit 6 detects the voltage of the electrolytic capacitor C1 and controls turning on/off of a switching element Q1.

[0023] The DC/DC conversion unit 3 is a step-down chopper 20 circuit made up of a switching element Q2, a diode D6, an inductance L2, and a capacitor C2, and a resistor R0 for detecting lamp current is inserted in series to the ground side of the output end of the step-down chopper. The control circuit 5 adjusts turning on/off of the switching element Q2, whereby 25 the DC/AC conversion unit 4 at the following stage can control

the value of the lamp current supplied to the high-pressure discharge lamp DL.

[0024] The DC/AC conversion unit 4 is implemented as an inverter of full bridge type wherein a series circuit of switching elements Q3 and Q4 and a series circuit of switching elements Q5 and Q6 are connected in parallel and a series circuit of an igniter IG for starting the high-pressure discharge lamp DL and the high-pressure discharge lamp DL is connected between the connection point of the switching elements Q3 and Q4 and the connection point of the switching elements Q5 and Q6. The switching elements Q3, Q4, Q5, and Q6 are turned on/off according to a signal output through a drive circuit 72 from a low-frequency oscillator 71 of a control circuit 7, and a state in which the switching elements Q3 and Q6 are on and the switching elements Q4 and Q5 are off and a state in which the switching elements Q3 and Q6 are off and the switching elements Q4 and Q5 are on are repeated alternately at a frequency of about several 100 Hz. Thus, a current IDL flowing into the high-pressure discharge lamp DL becomes a rectangular wave at about several 100 Hz.

[0025] The control circuit 5 is made up of the lamp current command value computation circuit 52 for receiving a signal from the dimmer 2 and outputting a lamp current command value I_{la}^* , an operational amplifier OP1 having a plus terminal to which the lamp current command value I_{la}^* is input, and a drive

circuit 54 for controlling turning on/off of the switching element Q2 based on the pulse width responsive to the output level of the operational amplifier OP1. A signal of the lamp current I_{la} detected from one end of the resistor R0 provided
5 in the DC/DC conversion unit 3 is input through a resistor R1 to a minus terminal of the operational amplifier OP1, a resistor R2 is connected between the minus terminal and an output terminal of the operational amplifier OP1, and the operational amplifier OP1 performs feedback operation so that the lamp
10 current command value I_{la}^* matches the command value I_{la}^* .

[0026] The lamp current command value computation circuit 52 adopts the sum of DC voltage source V^* varied by the dimmer 2 and detection voltage V_{la} provided by dividing the voltage of the output end of the DC/DC conversion unit 3, namely, the
15 lamp voltage of the high-pressure discharge lamp DL through resistors R3 and R4 as the lamp current command value I_{la}^* . For averaging, a capacitor C3 is connected in parallel with the resistor R4. If the resistors R3 and R4 and the capacitor C3 do not exist in the circuit, the output voltage of the DC
20 voltage source V^* adjusted by the dimmer 2 becomes the lamp current command value I_{la}^* as it is, in which case constant-current control for making the lamp current constant regardless of the lamp voltage is conducted; in the embodiment, however, the component of the detection voltage V_{la} responsive
25 to the lamp voltage is also fed back and is added, so that the

output characteristic of increasing the lamp current in response to the lamp voltage as shown in FIG. 1 (b) can be realized comparatively easily. Although not shown in FIG. 3, the lamp voltage is also detected in a lamp light determination circuit and an anomaly protection circuit and thus they can also be used as the circuit, needless to say.

[0027] FIGS. 4 (a) and 4 (b) show measurement data provided when dimming control of a high-pressure discharge lamp is actually performed using the invention; FIG. 4 (a) represents the lamp power W relative to the lamp voltage V at the ratio with the value at the rated lighting time of the lamp being 100% for both the voltage and the power. Lines indicated by dim1, dim2, dim3, and dim4 indicate the output characteristic of the lighting device measured as a variable resistor is connected in place of a high-pressure discharge lamp at one dimming level, and correspond to BC1 described with reference to FIG. 1 (a). LC indicates the lamp characteristic when the lamp is actually lighted in place of the variable resistor, and corresponds to LC in FIG. 1 (a). Breaking off of the solid line LC at the dimmer lower limit indicates going out or occurrence of fierce flicker. It is seen in the figure that going out does not occur and the lamp is stably lighted even in an area where the lamp voltage rapidly rises.

[0028] FIG. 4 (b) represents the lamp current I relative to the lamp voltage V at the ratio with the value at the rated

lighting time of the lamp being 100% for both the voltage and the current. Lines indicated by dim1, dim2, dim3, and dim4 indicate the output characteristic of the lighting device measured as a variable resistor is connected in place of a 5 high-pressure discharge lamp at one dimming level, and correspond to BC1 described with reference to FIG. 1 (b). LC indicates the lamp characteristic when the lamp is actually lighted in place of the variable resistor, and corresponds to LC in FIG. 1 (b). It is seen in FIG. 4 (b) that it shows the 10 same characteristic as the characteristic shown in FIG. 1 (b) wherein the output current of the lighting device at one dimming level grows in response to an increase in the lamp voltage.

[0029] For comparison, an experiment was conducted in a similar manner in constant-current control with addition of 15 none of the resistors R3 and R4 and the capacitor C3 in FIG. 3. FIGS 5 (a) and 5 (b) show the result. Symbols in FIGS 5 (a) and 5 (b) are similar to those in FIGS 4 (a) and 4 (b) and therefore will not be discussed again. As compared with FIG. 4, it is obviously seen that the dimming lower limit of LC at 20 the lamp lighting time does not lower as that in FIG. 4. That is, it is obviously seen that dimming is possible up to about 20(%) of the rating of lamp power and up to about 16(%) of the rating of lamp current in the invention in FIG. 4, whereas dimming in the constant-current control in FIG. 5 does not reach 25 them.

[0030] According to the embodiment, low luminous lighting can be stably executed in a wider range as compared with the constant-current control. The ratio of (change amount of lamp current/ change amount of lamp voltage) is made roughly 5 constant, whereby control can be facilitated and can be realized by a simple control circuit.

[0031] (Second embodiment)

FIGS. 6 (a) and (b) show the operation characteristics of a discharge lamp lighting device according to a second 10 embodiment of the invention. In the figures, LC indicates the lamp characteristic and lines indicated by BC₁, BC_{1'}, and BC_{1''} indicate the output characteristic of the lighting device. FIG. 6 (a) differs from FIG. 1 (a) in that the gradient of the output characteristic of the lighting device is increased as 15 dimming becomes deeper. Such control is performed, whereby the output characteristic of the lighting device and the lamp characteristic cross more orthogonally even in a low luminous area where the lamp voltage rapidly changes, so that it is made possible to maintain the operation point reliably. Although 20 a circuit is not shown, for example, detection value V_{la} detected by a lamp voltage detection circuit may be squared for use, etc., and it can be accomplished comparatively easily.

[0032] FIG. 6 (b) is a graph provided by converting the vertical axis in FIG. 6 (a) into lamp current I and shows those 25 corresponding to the lamp characteristic LC and the output

characteristic of the lighting device BC1, BC1', and BC1" in FIG. 6 (a). It is also seen in FIG. 6 (b) that when dimming is deepened, the output characteristic of the lighting device and the lamp characteristic cross more orthogonally.

5 According to the embodiment, if dimming is deepened, the operation point is provided reliably, so that low luminous lighting can be stably executed in a wider range.

[0033] (Third embodiment)

FIGS. 7 (a) and (b) show the operation characteristics 10 of a discharge lamp lighting device according to a third embodiment of the invention. FIG. 7 (a) differs from FIG. 1 (a) in that constant-current control is adopted for the output characteristic of the lighting device in the lamp voltage range of 0 to Vth. The same description as in the first embodiment 15 applies to an area where the lamp voltage is larger than Vth, namely, an area where the lamp voltage is larger than point A of the output characteristic of the lighting device.

[0034] Generally, after a high-pressure discharge lamp is started by a starter circuit like an igniter, lamp voltage 20 gradually grows from the vicinity of 0 (V). Output characteristic is provided reliably from voltage 0 (V), so that the lamp operation point shifts on BC1 in FIG. 7 (a) and, for example, dimming starting can be executed. Although not shown in the figure, a measure of current needs to be allowed to flow 25 for several 10 seconds just after the lamp is started and

therefore FIG. 7 (a) shows the characteristic after the time.

[0035] FIG. 7 (b) is a graph provided by converting the vertical axis in FIG. 7 (a) into lamp current I and shows those corresponding to the lamp characteristic LC and the output characteristic of the lighting device BC1 in FIG. 7 (a). The lamp current is controlled constantly in the lamp voltage range of 0 to V_{th} and when the lamp voltage becomes larger than V_{th} , the lamp current command value is also increased in response to an increase in the lamp voltage.

[0036] FIG. 8 shows the circuit configuration of the embodiment. FIG. 8 differs from FIG. 2 in that a lamp voltage detection circuit 55 for detecting the voltage across a high-pressure discharge lamp DL and a circuit made up of a comparator COMP1 for making a comparison between a detection value V_{la} of the detection circuit 55 and a DC voltage v_{th} and a switch SW for switching a lamp current command value I_{la}^* between V_{bc1} and V_{bc2} depending on output of the comparator COMP1 are added to a control circuit 5 and that the output voltage of a variable voltage source V_{dim} is made variable according to a signal from a dimmer 2, whereby the value of V_{bc2} can be adjusted. Using the circuit, a circuit wherein characteristic changes based on the lamp voltage V_{th} as shown in FIGS. 7 (a) and 7 (b) can be configured easily. To use the configuration illustrated in FIG. 3 as a lamp current command value computation circuit 52, a circuit made up of resistors

R3 and R4 and a capacitor C3 can also be used as the lamp voltage detection circuit 55.

[0037] In the time period during which the lamp voltage detection signal V_{la} is smaller than predetermined DC voltage 5 V_{th} , the comparator COMP1 outputs low, causing the switch SW to switch into V_{bc2} . When the switch SW switches into V_{bc2} , the lamp current command value I_{la}^* becomes V_{dim} set arbitrarily by a signal from the dimmer 2, thus resulting in constant-current control responsive to each dimming level. 10 After the lamp is started, the lamp voltage gradually increases and when the lamp voltage detection signal V_{la} exceeds the predetermined DC voltage V_{th} , the comparator COMP1 outputs high, causing the switch SW to switch into V_{bc1} . In this case, similar control to that previously described in the first 15 embodiment is performed, so that low luminous lighting can be stably executed.

[0038] According to the embodiment, after start, the output characteristic of the lighting device is provided from lamp voltage 0 V to the voltage at the operation point, so that 20 dimming starting can be executed reliably with low luminous flux, for example. It can be implemented as a simple control circuit.

[0039] (Fourth embodiment)

FIGS. 9 (a) and (b) show the operation characteristics 25 of a discharge lamp lighting device according to a fourth

embodiment of the invention. The embodiment differs from the third embodiment in that the value of the switch point V_{th} of the control operation in the third embodiment is increased as dimming becomes deeper.

5 [0040] A description is given below with FIG. 9 (a): In the figure, output characteristic of the lighting device BC1 passing through points A and B is the same as the characteristic shown in the third embodiment. When the lamp voltage reaches V_{th1} , the control operation switches at the point A in the 10 figure and the lamp is lighted at the intersection point of the output characteristic of the lighting device BC1 and lamp characteristic LC. FIG. 9 (b) is a graph provided by converting the vertical axis in FIG. 9 (a) into lamp current I and shows those corresponding to the lamp characteristic LC and the 15 output characteristic of the lighting device BC1, BC1', and BC1" in FIG. 9 (a).

[0041] Next, if an attempt is made to deepen dimming with the circuit shown in the third embodiment intact, the value of V_{th1} remains unchanged and thus the output characteristic 20 of the lighting device shifts from BC1 described above to BC1'. However, in an area where the lamp voltage is larger than V_{th1} , the characteristics of BC1 and BC1' are characteristics close to orthogonality with the lamp characteristic LC and thus the operation point change amount is small and thus brightness 25 change is hard to see although lighting maintenance is good.

If the gradient of the line from point A' to point B' is made gentle to provide a brightness difference from BC1, a brightness difference is provided, in which case going out easily occurs.

5 [0042] Then, to execute deeper dimming from the output characteristic of the lighting device BC1, the switch point is changed from Vth1 to Vth2, whereby the output characteristic of the lighting device becomes as BC1" and the brightness difference can be increased with the same gradient intact as
10 compared with BC1'. Therefore, the value of the switch point Vth is changed arbitrarily in response to the lamp voltage, so that fine adjustment of the brightness at the dimming time is made possible. If the light output difference is too large with respect to the dimming level, control may be performed
15 in the direction of decreasing the switch point Vth in response to the lamp voltage.

[0043] FIG. 10 shows the circuit configuration of the embodiment. FIG. 10 differs from FIG. 8 in that detection value Vla of a lamp voltage detection circuit 55 controls the DC
20 voltage Vth determining the voltage at the switch point of the control operation. The circuit is thus configured, whereby the value of Vth also grows as the lamp voltage increases, so that the output characteristic of the lighting device like BC1"
in FIG. 9 (a), (b) can be obtained.

25 [0044]

The circuit may be configured so as to perform variable control of the voltage of DC voltage source V_{th} in response to the magnitude of a dimming signal as shown in FIG. 11. Variable control of the magnitude of the DC voltage V_{th} is 5 performed in response to the magnitude of the dimming signal, for example, in such a manner that if the dimming signal has a magnitude of passing through the point A in FIG. 9 (a), (b), the switch point is set to V_{th1} and if the dimming signal has a magnitude of passing through a point A" in FIG. 9 (a), (b), 10 the switch point is set to V_{th2} .

[0045] According to the embodiment, the voltage at the switch point between constant-current control and the control operation of low luminous lighting according to the invention is changed in response to the depth of dimming, so that 15 brightness adjustment in a low luminous area can be made easily.

[0046] (Fifth embodiment)

FIG. 12 shows the operation characteristics of a discharge lamp lighting device according to a fifth embodiment of the invention. The embodiment is an embodiment for reliably 20 executing low luminous lighting even in a state in which a lamp has been lighted for a long term and is at the last stage of the life, for example.

[0047] In FIG. 12, lamp characteristic LC and output characteristic of the lighting device BC are similar to those 25 described in the third and fourth embodiments. When the lamp

is lighted for a long term, the lamp voltage becomes high and thus the lamp characteristic LC shifts to the right and before long, becomes a characteristic like LC' indicated by the dotted line. Therefore, to provide the same lamp power as that at 5 the operation point of the lamp indicated by the intersection point of the lamp characteristic LC and the output characteristic of the lighting device BC1 if the lamp is lighted for a long term, the dimming level may be lowered in response to the lighting time and the value of a switch point Vth1 may 10 also be increased as in the fourth embodiment, and the switch point with the value increased becomes Vth3. The output characteristic of the lighting device to switch to at Vth3 is BC1' indicated by the alternate long and short dash line, and the lamp power at the intersection point of LC' and BC1' can 15 be set to almost the same as the lamp power at the intersection point of LC and BC1 described above.

[0048] FIG. 13 shows the circuit configuration to accomplish the characteristic in FIG. 12. FIG. 13 differs from FIG. 10 in that instead of performing variable control of the 20 DC voltage source Vth according to the lamp voltage detection value in FIG. 10, the output value of a DC voltage source Vth is gradually increased with the passage of lighting time with a lighting time integrating timer 56 and that the output value of a DC voltage source Vdim determining the gradient from a 25 point A to a point A' in FIG. 12 is also changed according to

an output signal of the lighting time integrating timer 56. The output value of the DC voltage source Vdim is decreased with the passage of the lighting time. Other points are the same as those in FIG. 10 and therefore will not be discussed
5 again.

[0049] If the lamp is lighted for a long term like several 1000 hours, illuminance tends to lowers as a whole because of blackening of an arc tube or the like and thus in fact it is desirable that the operation point after lighting for a long 10 term should be set a little larger than that at the initial time. That is, the lamp power in the vicinity of the dimming lower limit is set larger than that at the initial time for variation of the lamp with time, so that illuminance at the same degree as that at the initial time of lighting the lamp 15 can be obtained.

[0050] According to the embodiment described so far, the output characteristic of the lighting device can be accomplished comparatively easily because of the characteristic that the lamp power and the lamp current 20 increase relative to the lamp voltage; for example, even the circuit as shown in FIG. 3 can handle simply by changing a constant.

[0051] As described above, according to the embodiment, the lamp power in the vicinity of the dimming lower limit can 25 be set to power at the same degree as that at the initial time

for variation of the lamp with time. The lamp power in the vicinity of the dimming lower limit is set larger than that at the initial time for variation of the lamp with time, so that illuminance at the same degree as that at the initial time 5 of lighting the lamp can be obtained.

[0052] (Sixth embodiment)

FIGS. 14 (a) and (b) show the operation characteristics of a discharge lamp lighting device according to a sixth embodiment of the invention. The embodiment performs 10 continuous dimming control from rated lighting to the dimming lower limit of low luminous flux and suppresses an unstable phenomenon occurring at the switching time of different control between constant-power control and constant-current control, for example.

[0053] A detailed description is given below: In FIG. 14 (a), the output characteristic at a related lighting point CP1 of intersection points CP1, CP2, ..., CP6 of lamp characteristic LC indicated by the solid line and output characteristic of the lighting device indicated by dotted lines 15 is BC1 and the output characteristic changes as BC2, BC3, ..., BC6 in response to deepening of dimming. FIG. 14 (b) is a graph corresponding to FIG. 14 (a) with the lamp current on the vertical axis; points indicated by CP1, CP2, ..., CP6 indicate the intersection points of the lamp characteristic LC and the 20 output characteristic of the lighting device BC1, BC2, ..., BC6.

BC6 in FIG. 14 (a), so-called lamp operation points.

[0054] The BC1, BC2 output characteristic at the operation point CP1, CP2 is conventional constant-power control and is maintained almost at constant power in the 5 vicinity of the operation point if the lamp voltage changes. The BC4 output characteristic at the operation point CP4 is constant-current control as shown in the related art example and is maintained almost at constant current in the vicinity of the operation point if the lamp voltage changes. The BC3 10 output characteristic at the operation point CP3 is intermediate control of the constant-power control and the constant-current control described above and the lamp power increases and the lamp current decreases in response to an increase in the lamp voltage. The BC5, BC6 output 15 characteristic at the operation point CP5, CP6 is control of increasing the lamp current with an increase in the lamp voltage as described in the embodiments. These types of control are performed continuously in response to the dimming level, whereby smoother dimming can be realized from the rated 20 lighting to the dimming lower limit. Since the conventional constant-power control is applied in the vicinity of the rated lighting, when the lamp voltage fluctuates, excessive power is not added to the lighting device.

[0055] FIG. 15 is a graph indicating lamp power on the 25 horizontal axis and lamp current change amount ΔI /lamp voltage

change amount ΔV on the vertical axis and corresponds to the gradient at each operation point in FIG. 14 (b). The gradient becomes a negative value in the CP1 vicinity implementing constant-power control and is gradually changed to 0 and
5 constant-current control is accomplished at the operation point CP4 where $\Delta I/\Delta V$ becomes 0. To maintain low luminous lighting from the point, the gradient is set to a positive value at the CP5, CP6 operation point.

[0056] FIG. 16 shows an example of an almost similar
10 characteristic to that in FIG. 14 (b). This is characterized by the fact that the output characteristic of the lighting device becomes symmetrical with lamp current I_L as the boundary. In FIG. 16, the operation points are indicated by white circles as in FIG. 14 (b). Such a symmetrical characteristic is
15 provided, whereby when the output characteristic is put into a data table of a microcontroller, etc., for example, the symmetry can be used to about halve the data amount.

[0057] FIG. 17 shows a circuit example for accomplishing the output characteristic in FIG. 14 (b). The output
20 characteristic in FIG. 14 (b) is previously retained in a data table of a microcontroller, etc., and a lamp current command value I_{La}^* is determined by a lamp voltage detection value V_{La} and a dimming signal from a dimmer. In the figure, if a value of V_{Lal} is detected as the lamp voltage and the dimming signal
25 from the dimmer is a level of Dim5, $I(Dim5)$ is selected as the

lamp current command value from characteristic drawing of the data table and is output as the command value I_{la}^* . If all characteristics $Dim_1, Dim_2, \dots, Dim_6$ from the rating to deep dimming are thus put into the data table, a switching circuit 5 at V_{th} as used with the embodiments described above becomes unnecessary and the control circuit can be simplified.

[0058] According to the embodiment, smooth and continuous control can be executed in a wide range of the rated lighting to the dimming lower limit using the conventional 10 constant-power control, the intermediate control of the constant-power control and the constant-current control, the constant-current control, and the low luminous lighting control described so far in combination. The data table of the microcontroller is referenced, whereby the operation 15 switching circuit responsive to the lamp voltage, etc., becomes unnecessary and the circuit configuration can be simplified.

[0059] In the embodiment, the circuit example of using a step-up chopper circuit, a step-down chopper circuit, and an inverter of full bridge type in combination is shown in FIG. 20 3 as the configuration of the main circuit, but the invention is not limited to it. For example, a circuit as shown in FIG. 18, 19, or 20 may be adopted and the waveform of the lamp current need not be a rectangular wave at about several 100 Hz and may be a high-frequency sine wave, etc., needless to say. It is 25 essential that the control be control for providing the

characteristic as shown in FIG. 1 (a), (b) as the output characteristic of the lighting device.

[0060] In a circuit example in FIG. 18, a commercial AC power supply Vs is rectified by a full-wave rectifier made up
5 of diodes D1 to D4 and is converted into a DV voltage by a step-up chopper circuit made up of an inductor L1, a switching element Q1, a diode D5, and a smoothing capacitor C1, the DV voltage is converted into an AC voltage by a full-bridge inverter circuit made up of switching elements Q3, Q4, Q5, and Q6, and
10 the AC voltage is supplied through an igniter IG to a high-pressure discharge lamp DL.

[0061] A circuit example in FIG. 19 uses a half-bridge inverter circuit to which a series circuit of electrolytic capacitors C1 and C2 is connected in place of the series circuit
15 of the switching elements Q5 and Q6 in the circuit example in FIG. 18. An igniter IG is made up of a step-up pulse transformer and a pulse generation circuit and at the starting time, the pulse generation circuit generates a pulse voltage, whereby a high-voltage pulse is applied from the secondary side of the
20 pulse transformer to a high-pressure discharge lamp DL. The DC voltage of the electrolytic capacitors C1 and C2 is subjected to variable control as turning on/off of the switching element Q1 is controlled. The configuration of the DC-DC converter is not limited to the step-up chopper shown in the figure and
25 any desired circuit configuration of a step-down chopper, a

step-up and step-down chopper (inversion-type chopper), a flyback DC-DC converter, or the like can be used, needless to say.

[0062] In a circuit example in FIG. 20, in place of igniter 5 IG of a separate circuit, a resonance circuit made up of an inductance L2 and a capacitor C3 is connected to both ends of a switching element Q4 through a coupling capacitor C2 and at the starting time, switching elements Q3 and Q4 are turned on and off alternately in the vicinity of the resonance frequency, 10 whereby a starting high voltage is generated and at the lighting time, the switching elements Q3 and Q4 are turned on and off alternately at the frequency responsive to the lamp power, whereby continuous output control can be executed in a wide range of the rated lighting to the dimming lower limit.

[0063] The high-pressure discharge lamp lighting device described so far is built in a lighting fixture, for example, as shown in FIG. 21 or a lighting system for controlling the lighting fixtures for use. In the figure, numeral 8 denotes an electronic ballast, numeral 9 denotes lamp wiring, and 20 numeral 10 denotes a reflecting plate. Here, a down light is illustrated as the lighting fixture, but the high-pressure discharge lamp lighting device can also be applied to a spot light or any other desired lighting fixture, needless to say.

[0064] While the invention has been described in detail 25 with reference to the specific embodiments, it will be obvious

to those skilled in the art that various changes and modifications can be made without departing from the spirit and the scope of the invention.

This application is based on Japanese Patent Application
5 (No. 2004-091111) filed on March 26, 2004, which is incorporated herein by reference.

Industrial Applicability

[0065] According to the invention as claimed in claim 1, low luminous lighting can be stably executed in a wider range
10 as compared with the constant-current control in the related art.

According to the invention as claimed in claim 2, change amount of lamp current/change amount of lamp voltage is made constant, whereby control can be facilitated.

15 According to the invention as claimed in claim 3, if dimming is deepened, the operation point is provided reliably, so that low luminous lighting can be stably executed in a wider range.

According to the invention as claimed in claim 4, after
20 start, the output characteristic of the lighting device is provided from lamp voltage 0 V to the voltage at the operation point, so that low luminous dimming starting can be executed reliably, for example.

According to the invention as claimed in claim 5, the
25 value of the lamp voltage at the switch point between

constant-current control and the operation according to the invention is changed in response to dimming, so that brightness adjustment in a low luminous area can be made easily.

[0066] According to the invention as claimed in claim 6, 5 the lamp power in the vicinity of the dimming lower limit can be set to power at the same degree as that at the initial time for variation of the lamp with time.

According to the invention as claimed in claim 7, smooth and continuous control can be executed in a wide range of the 10 rated lighting to the dimming lower limit using the constant-power control, the intermediate control of the constant-power control and the constant-current control, the constant-current control, and the low luminous lighting time control of the invention in combination.

15 According to the invention as claimed in claim 8, 9, 10, control can be facilitated and can be realized by a simple control circuit.

According to the invention as claimed in claim 11, the data table of the microcontroller is referenced, whereby the 20 control operation switching circuit responsive to the lamp voltage, etc., becomes unnecessary and the circuit can be simplified.

According to the invention as claimed in claim 12, the amount of data to be stored in the data table of the 25 microcontroller can be lessened.

According to the invention as claimed in claim 13, a lighting fixture that can be dimmed up to a lower level than that in the related arts can be provided.